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A Complete Plane Stress FEM Program

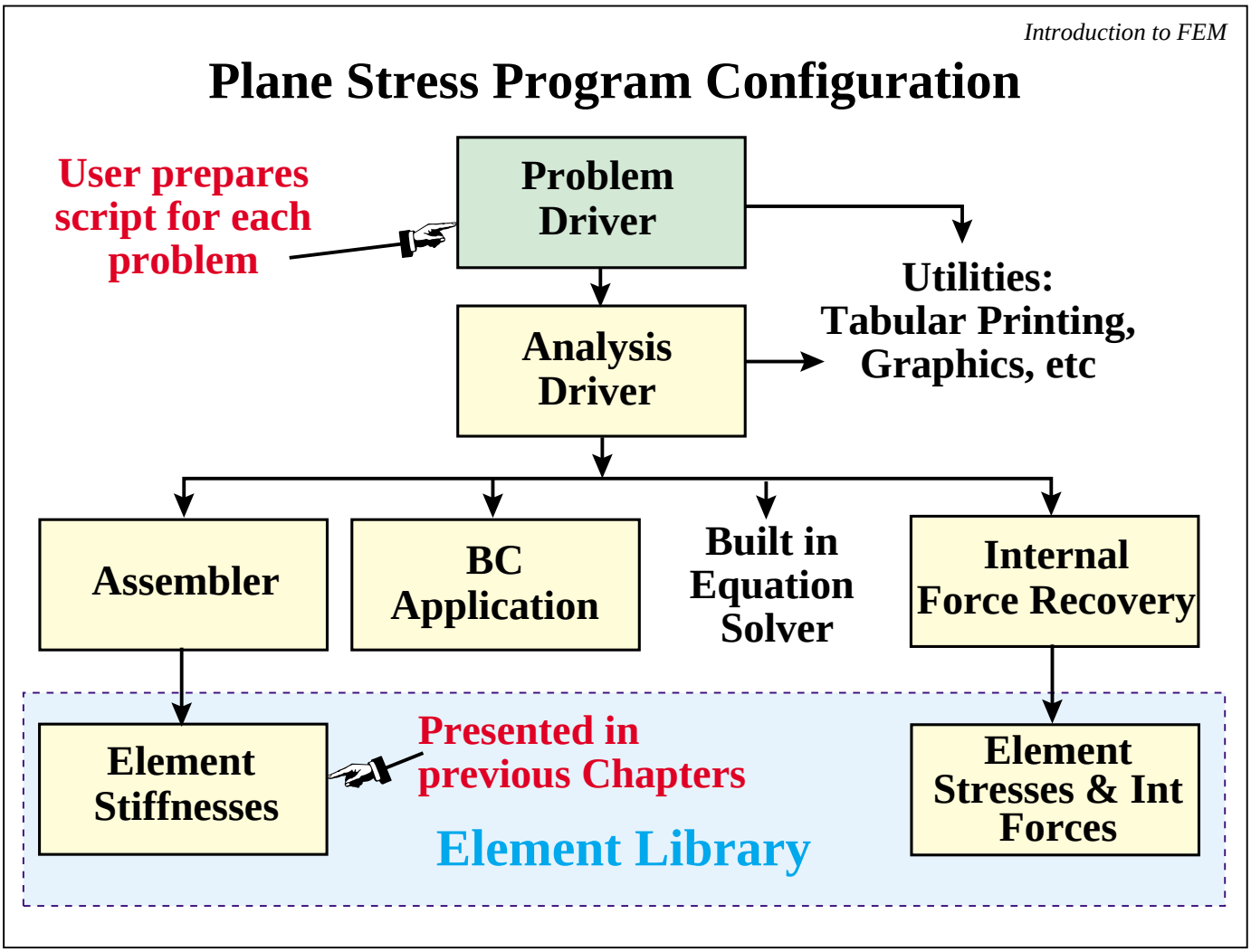
The 3 Basic Stages of a FEM-DSM Program

Preprocessing **: defining the FEM model**

Processing **: setting up the stiffness equations and solving for displacements**

Postprocessing **: recovery of derived quantities and presentation of results**

Plane Stress Program Configuration



Problem Definition Data Structures

Geometry Data Set:

NodeCoordinates

Element Data Set:

ElemTypes, ElemNodes,
ElemMaterials, ElemFabrications

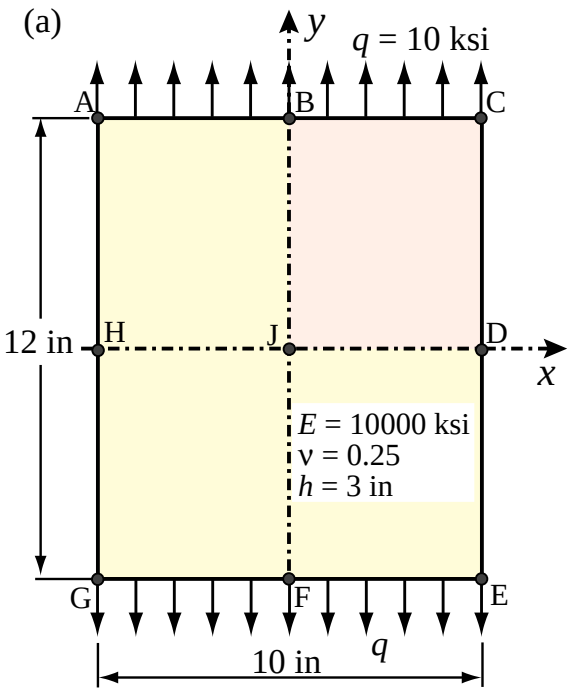
Degree of Freedom Activity Data Set:

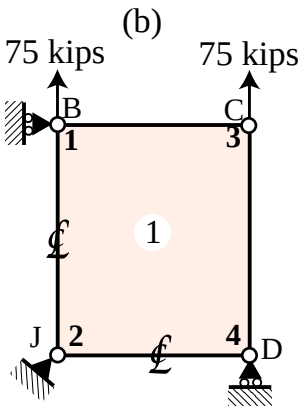
NodeDOFTags, NodeDOFValues

Processing Data Set:

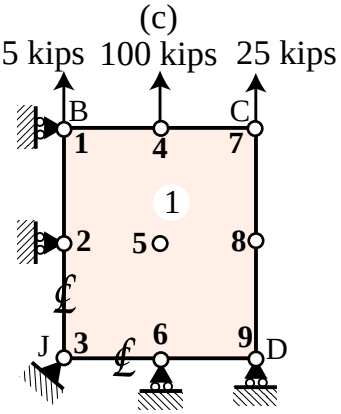
ProcessOptions

Benchmark to Illustrate Problem Definition (one-element models)





Model (I):
4 nodes, 8 DOFs,
1 bilinear quad

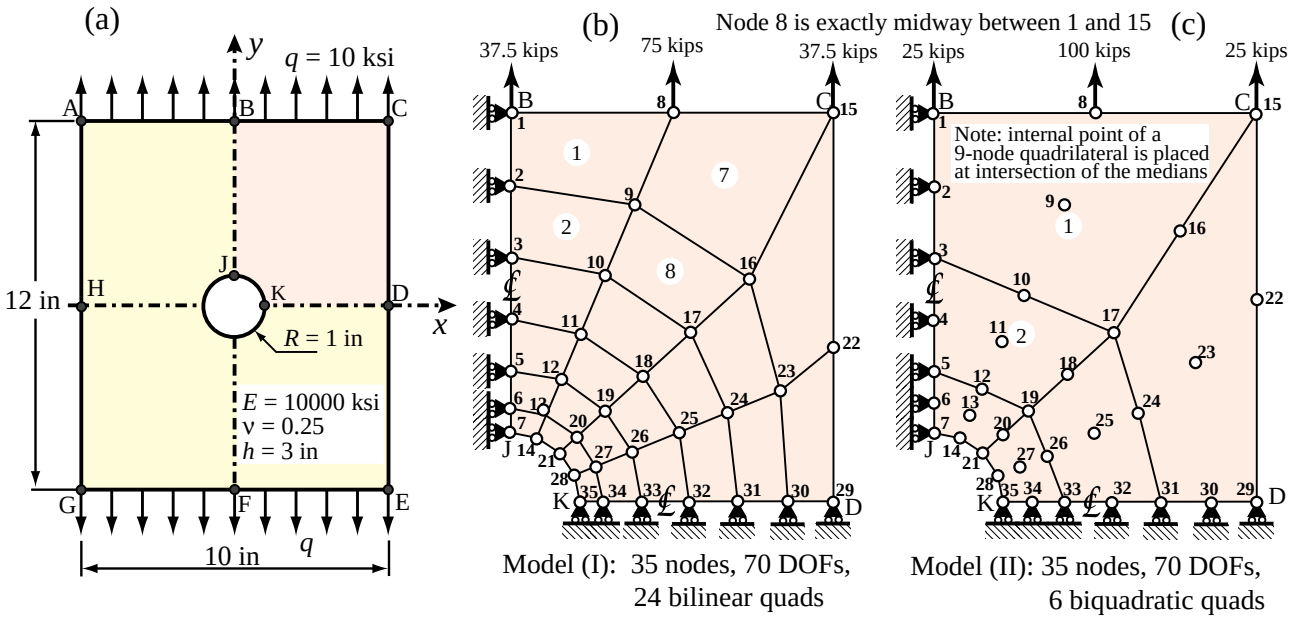


Model (II):
9 nodes, 18 DOFs,
1 biquadratic quad

Global node numbers shown

Benchmark Problem: Plate with Central Circular Hole

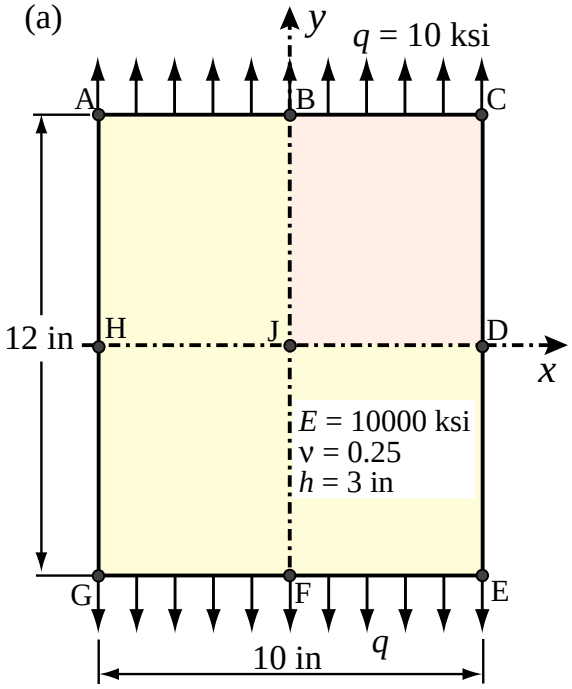
used in final exam and part of today's demo

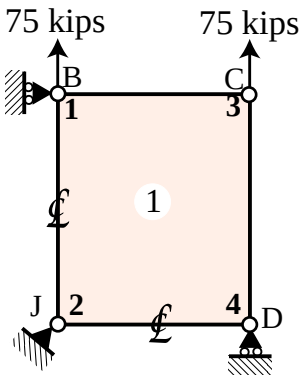


Model (I): 35 nodes, 70 DOFs, 24 bilinear quads

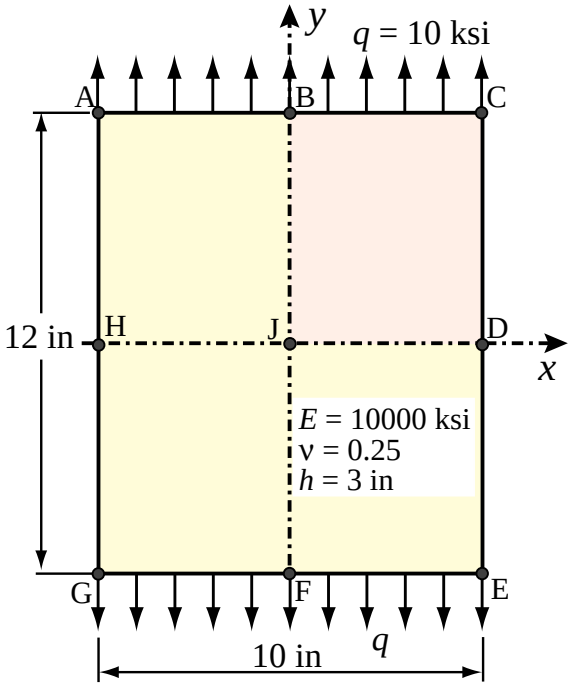
Model (II): 35 nodes, 70 DOFs, 6 biquadratic quads

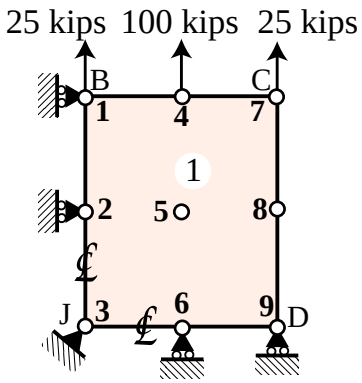
Geometry Data: 4-Node Quad Model



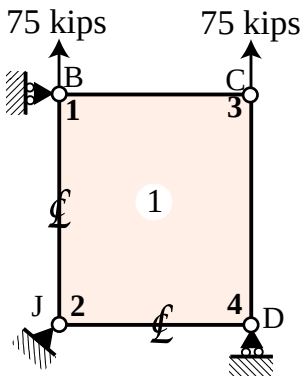


Geometry Data: 9-Node Quad Model

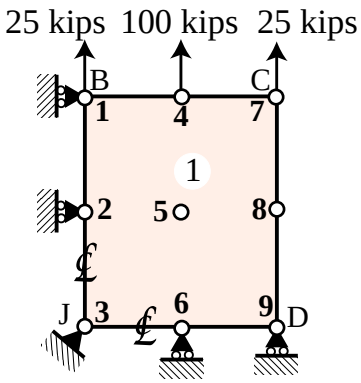




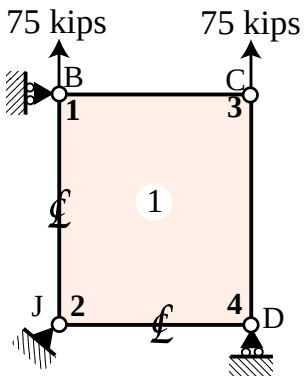
Element Data: 4-Node Quad Model



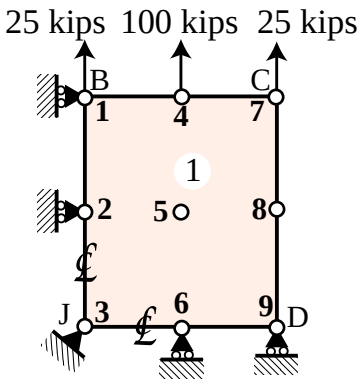
Element Data: 9-Node Quad Model



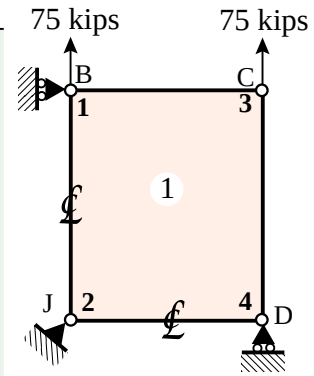
Freedom Activity Data: 4-Node Quad Model



Freedom Activity Data: 9-Node Quad Model



A Complete Problem Script Cell
Part 1: Preprocessing

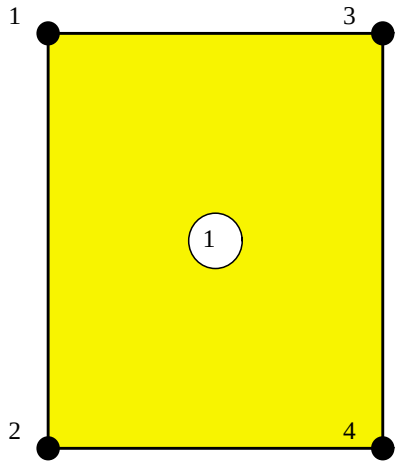



```
ClearAll[Em,ν,th];
Em=10000; ν=.25;  th=3; aspect=6/5; Nsub=4;
Emat=Em/(1-ν^2)*{{1,ν,0},{ν,1,0},{0,0,(1-ν)/2}};

(*  Define FEM model *)

NodeCoordinates=N[{{0,6},{0,0},{5,6},{5,0}}];
PrintPlaneStressNodeCoordinates[NodeCoordinates,"",{6,4}];
ElemNodes=  {{1,2,4,3}};
numnod=Length[NodeCoordinates]; numele=Length[ElemNodes];
ElemTypes=       Table["Quad4",{numele}];
PrintPlaneStressElementTypeNodes[ElemTypes,ElemNodes,"",{}];
ElemMaterials=   Table[Emat,   {numele}];
ElemFabrications=Table[th,     {numele}];
PrintPlaneStressElementMatFab[ElemMaterials,ElemFabrications,"",{}];
NodeDOFValues=NodeDOFTags=Table[{0,0},{numnod}];
NodeDOFValues[[1]]=NodeDOFValues[[3]]={0,75}; (* nodal loads *)
NodeDOFTags[[1]]={1,0};     (* vroller @ node 1 *)
NodeDOFTags[[2]]={1,1};     (* fixed node 2     *)
NodeDOFTags[[4]]={0,1};     (* hroller @ node 4 *)
PrintPlaneStressFreedomActivity[NodeDOFTags,NodeDOFValues,"",{}];
ProcessOptions={True};
Plot2DElementsAndNodes[NodeCoordinates,ElemNodes,aspect,
    "One element mesh - 4-node quad",True,True];
```

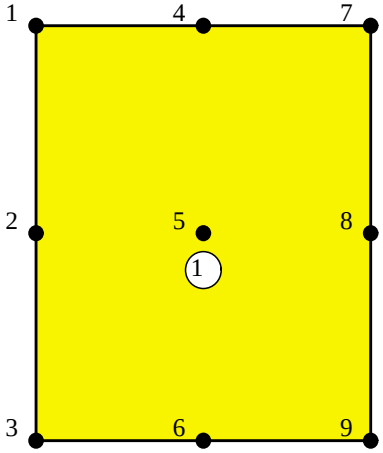
Mesh Plot Showing Element & Node Numbers

Produced by previous script

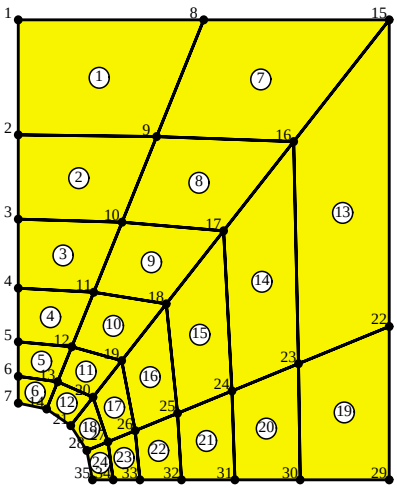
One element mesh - 4 node quad



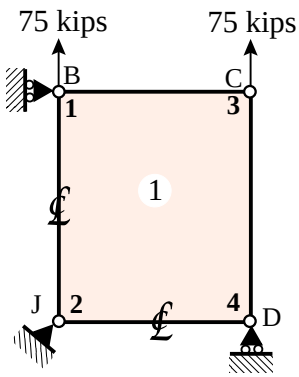
One element mesh - 9 node quad



One element mesh - 4 node quad



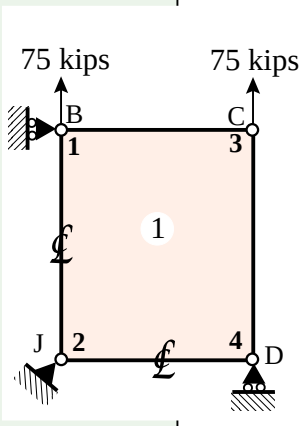
A Complete Problem Script Cell
Part 2: Processing



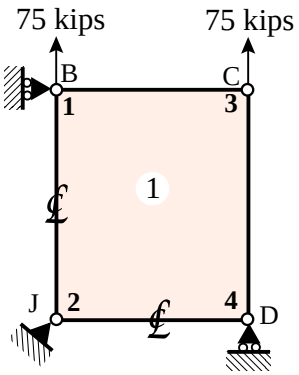

```
(*  Solve problem and print results *)

{NodeDisplacements,NodeForces,NodePlateCounts,NodePlateStresses,
    ElemBarNumbers,ElemBarForces}= PlaneStressSolution[
    NodeCoordinates,ElemTypes,ElemNodes,
    ElemMaterials,ElemFabrications,
    NodeDOFTags,NodeDOFValues,ProcessOptions];
```

A Complete Problem Script Cell
Part 3: PostProcessing

```
PrintPlaneStressSolution[NodeDisplacements,NodeForces,NodePlateCounts,
      NodePlateStresses,"Computed Solution:",{}];

(*  Plot Displacement Components Distribution - skipped *)


(*  Plot Averaged Nodal Stresses Distribution *)

sxx=Table[NodePlateStresses[[n,1]],{n,numnod}];
syy=Table[NodePlateStresses[[n,2]],{n,numnod}];
sxy=Table[NodePlateStresses[[n,3]],{n,numnod}];
{sxxmax,syymax,sxymax}=Abs[{Max[sxx],Max[syy],Max[sxy]}];
ContourPlotNodeFuncOver2DMesh[NodeCoordinates,ElemNodes,
       sxx,sxxmax,Nsub,aspect,"Nodal stress sig-xx"];
ContourPlotNodeFuncOver2DMesh[NodeCoordinates,ElemNodes,
       syy,syymax,Nsub,aspect,"Nodal stress sig-yy"];
ContourPlotNodeFuncOver2DMesh[NodeCoordinates,ElemNodes,
       sxy,sxymax,Nsub,aspect,"Nodal stress sig-xy"];
```



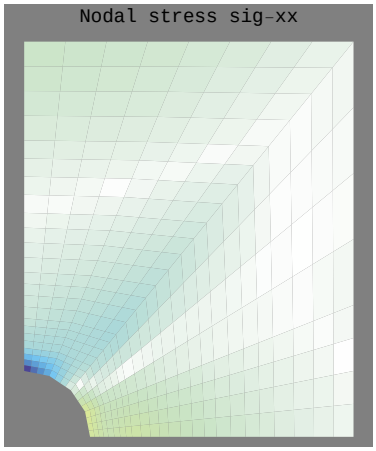
Solution Printout (Required in Exam Problems)

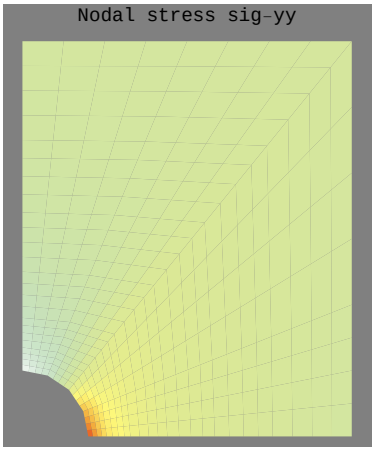


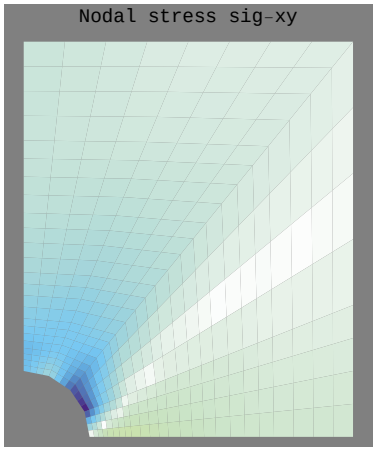
Computed Solution:

node	x-displ	y-displ	x-force	y-force	sigma-xx	sigma-yy	sigma-xy
1	0.0000	0.0060	0.0000	75.0000	0.0000	10.0000	0.0000
2	0.0000	0.0000	0.0000	−75.0000	0.0000	10.0000	0.0000
3	−0.0013	0.0060	0.0000	75.0000	0.0000	10.0000	0.0000
4	−0.0013	0.0000	0.0000	−75.0000	0.0000	10.0000	0.0000

Stress Contour Plots







Stress Contour Plots (cont'd)

sigma-yy stress contour plot reconstructed over complete plate